Activated drains

Technology description:
General information & application area

Target Audience: Authorities, site owners, consultants, contractors

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Project website address: aquarehab.vito.be

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1 INTRODUCTION

The activated drain technology is an innovative in-situ technology to improve the quality of groundwater in a number of situations. The activated drain technology refers to trenches for draining water in which pollutant treatment processes (like for instance biodegradation, sorption, …) are stimulated and/or induced.

This technology description document intends to provide general information about this technology, and its application area and boundary conditions for authorities, consultants, contractors and site owners. The document was composed in the frame of the FP7 project AQUAREHAB (GA 226565), and comprises outcomes and lessons learned during this project. For more details the associated generic guideline can be consulted.

2 GENERAL PRINCIPLES OF THE ACTIVATED DRAIN TECHNOLOGY

2.1 CONCEPT

The activated drain technology refers to a (ground)water remediation approach where trenches/pipes are installed (1) to drain contaminated (ground)water and (2) in which pollutant treatment processes are stimulated and/or induced (Figure 1.A). This implies that the contaminated groundwater is treated while it is drained. The removal processes may be different processes like for instance biodegradation, sorption, chemical conversions, … and are to be selected in function of the pollutants that are present.

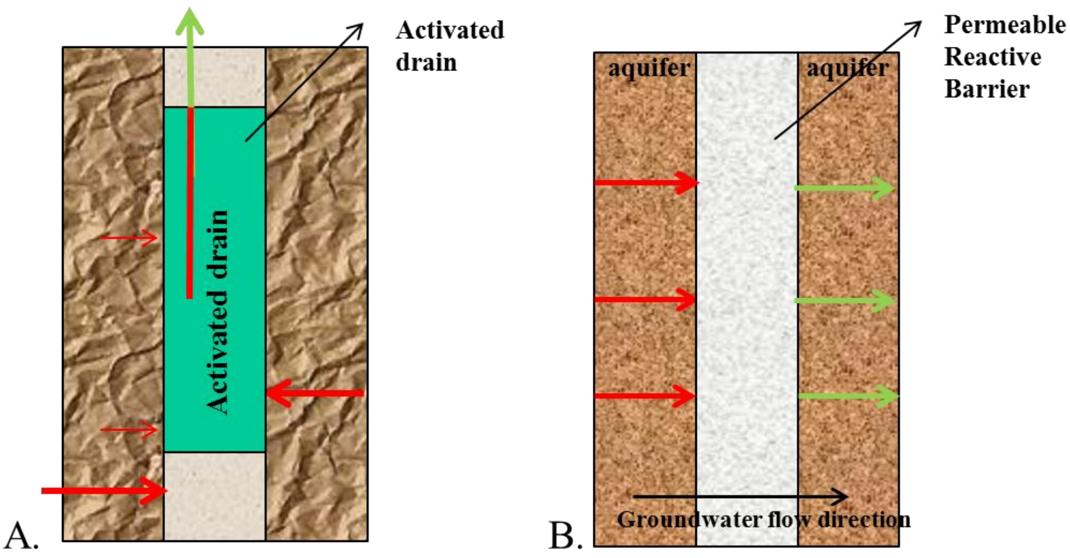

Figure 1. Schematic representation (top view) of (A) an activated drain and (B) permeable reactive barrier.

There are similarities between the activated drain technology (Figure 1.A) and the reactive permeable barrier (PRB) technology (Figure 1.B) as both aim (ground)water treatment in the subsurface in delineated permeable zones where pollutant removal processes are activated. The major difference, however, is the flow path and flow velocity of water in treatment zone. In activated drains the flow path is along the drain (which can easily be several 100 m) and the flow velocity is a function of the pumping rate at the end of the drain. On the other hand, in permeable reactive barriers the water generally flows in the direction of the groundwater flow and at the groundwater flow velocity, with a flow path across the thickness of the barrier (generally limited to 0.5 to a few meter).

2.2 TARGETED SUBSTANCES & REACTION MECHANISMS

In principle, the activated drain technology can be used to treat all pollutants for which a pollutant removal process is available that can be activated in the subsurface. An overview of some substances that can be targeted by the activated drain technology is given in **Table 1** along with potential emissions sources of the different substances and examples of associated removal processes.

Table 1 Examples of substances that can be tackled by the activated drain technology.

Targeted substances		Emission sources	Potential pollutant removal processes
Class	Specific substance		
CAHs (chlorinated aliphatic hydrocarbons)	Trichloroethene (TCE) Tetrachloroethene (PCE) Cis-dichloroethene (cDCE) Vinylchloride (VC) Chlorinated ethanes …	Drycleaner activities, degreasing activities, ...	• Chemical reduction via zerovalent iron (see DL4.3 part A) • Biodegradation-anaerobic (see DL4.3 part B) • Sorption...
BTEX	Benzene, Toluene, ethylbenzene & xylenens	Petrochemical industry Petrol gas filling stations	• Biodegradation – aerobic • Sorption
Inorganics	Ammonium	Landfill leachate	• Biologically: nitrification – denitrification • Ion exchange • ... •
Oxygenates	Methyl-tert-butyl ether (MTBE) Tert-butyl alcohol (TBA) …	Petrol gas Petrochemical industry	• Biodegradation – aerobic • ...
Metals	Nickel, zinc, ..	Metal industry	• Sorption • Bioprecipitation processes • ...
micropollutants	Herbicides, pesticides, biocides, pharmaceuticals …	Agriculture & industrial activities	• Biodegradation • sorption
…			•
Mixed pollutions	Mixtures of pollutants mentioned above	Industrial sites Overlapping groundwater plumes	combination of the above mentioned processes

2.3 Development stage of the technology

Within technology development, the following stages can be defined:

- A technology is very emerging when it is at the research stage (not even implemented in other sectors).
- It is emerging when it is implemented in another sector and is being developed in the concerned sector (but it is no at the pilot plant trial stage yet).
- It is becoming transferable when it is at the pilot plant trial stage in the concerned sector.
- It is transferable when it is at the full scale trial stage in the concerned sector.
- It is available when it is commercially available and in use in the concerned sector.

The activated drain technology is between 'emerging' and 'becoming transferable as':

- Subsurface drains have been used already for decades to funnel excess of water via for instance deep open drains or buried pipe drains.
- The activated drain technology has been studies on lab scale, but further research on smart carrier materials is needed to increase for instance the abatement rate for micropollutants.
- The activated drain has been studied on pilot scale in the field (for instance with the AQUAREHAB project).
- A number of practical aspects can be deduced from the reactive barrier technology, which has been studied extensively and has been demonstrated and applied at pilot and full scale.

3 Applicability and boundary conditions of the technology

The activated drain technology is especially useful for larger areas where contaminated water needs to be intercepted for treatment purposes and flooding prevention purposes. Two application areas are explained as examples:

Groundwater treatment in low permeability fractured rocks. The trench and field reactor technology is recommended only under the following conditions:

- The flow in the subsurface is via fractures or pumping wells and "traditional" PRBs are not an optional way to force the water to go through the degrading materials.
- When pollutants are present mostly in the dissolved phase.
- The depth of the groundwater contaminant plume is preferably not located deeper than 4-8 m bgs. For deeper plumes, the installation cost (digging trenches) will increase significantly.
- With respect to the hydrogeological characteristics of the site:
  - The groundwater flow direction is known and relatively stable during the year.
  - The type of matrix enables to dig trenches at reasonable costs.
  - The hydraulic conductivity of the trench porous materials (gravel) is higher than the permeability of the surrounding aquifer.
- The geochemical characteristics of the groundwater do not result in large quantities of precipitates, which can block the trench over time. For instance, when envisioning aerobic biodegradation, high levels of iron in the water may lead to clogging.
- The conditions of the drain water need to be compatible with the envisioned pollutant removal process. For instance, when envisioning aerobic biodegradation of pollutants,

  - High levels of dissolved oxygen are needed before entering the porous drainage system, or alternative oxygen delivery systems need to be used.
  - The water temperature must be kept within a certain range (for instance 25-37°C for biological processes studied within AQUAREHAB);
  - Pollutant degrading microorganisms need to be present. When possible, it is advised to use native bacteria, rather than introducing foreign microorganisms (even if they are adapted to the site conditions). However, there may be circumstances where addition of specialised bacteria (bioaugmentation) may be required.
  - Carrier materials that are compatible with the micro-organisms are to be used.
- The impact of co-pollutants in the groundwater on an envisioned removal process needs to be evaluated and taken into account when designing the activated drain.

Treatment of water pumped to prevent flooding. Nowadays, in many cities and areas around the world water is (semi)continuously pumped and drained to prevent flooding. The water in these industrialized areas can be polluted. The activated drain technology offers here a solution to treat the water before the discharge. As the amount of pumped water is largely influenced by the weather conditions, the water flow and hydraulic retention time can largely fluctuate in time.

4 PERFORMANCE OF THE ACTIVATED DRAIN TECHNOLOGY

The **abatement rate** can be defined as the substance concentration after the technology implementation divided by the substance concentration before implementation of the technology. The activated drain technology aims at an abatement rate close to 100%, which means that flux reduction rate in the drain for the pollutants is almost 100%. In situations where the activated drain technology is applied for micropollutants or complex mixtures of pollutants, the abatement rate can be lower. The local regulatory limits are determining for the exact targeted abatement rates that need to be taken into account during the barrier design.

Efficiency drivers are (1) the degradation/removal rates of the different pollutants and their breakdown products, (2) the water flow velocity in the drain, (3) the length of activated drain and (4) the inactivation of the activated drain over time (permeability & reactivity).

Longevity of the activated drain technology: In most cases, it is needed that the technology is operational for several years up to decades. Practically, there may be needs for additional investments during these long times as is the case for permeable reactive barriers.

5 COST OF THE TECHNOLOGY

Cost considerations for the trenches and the treatment system are comprised of: (1) the dimensions of the trench needed (depth, length and thickness, depending on flow characteristics); (2) the price of the reactors and their maintenance; (3) the local situation on the site (accessibility, surrounding buildings, underground constructions, type of subsurface); and (4) the local labour costs (country dependent).

6 GENERIC APPROACH TO DETERMINE APPLICABILITY OF A ACTIVATED DRAIN TECHNOLOGY FOR A SPECIFIC SITE OR AREA

For a successful application of the activated drain technologies, the following stepped approach is recommended:

Step 1: Site characterisation

A site characterisation is required for checking the application and boundary conditions associated with the technology (see section 3). The site characterisation comprises:

- Identification of the hydrology and collecting information on the geology (type of layer, permeability, ...) - Figure 2.
- Identification of the type and concentration of pollution that is present
- Evaluation of groundwater chemical data including conductivity, pH, redox potential, temperature, oxygen content as well as inorganic parameters such as Ca, Fe, K, Mg, Na, Si, Cl, SO_4, NO_3, alkalinity, TOC and DOC.
- Evaluation of the accessibility of the area

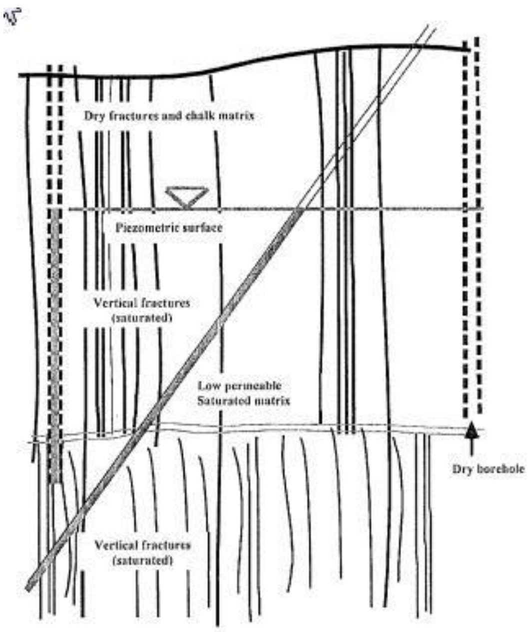

Figure 2. A schematic of a method to identify active fracture networks: inclined borehole crossing vertical fracture (after *Nativ et al.*, 2003)

Step 2: Selection of pollutant removal process

For the present pollutants that need to be reduced in concentration, potential pollutant removal processes need to be identified. In some cases small lab scale feasibility tests can have benefits. Next, a set of pollutant removal processes needs to be selected that can jointly cope with the present (mixed) pollution.

Step 3: Feasibility test at lab scale

Feasibility tests refer to lab scale test where the selected removal process(es) is/are evaluated more in detail. It is strongly advised to verify the functioning of the activated drain concept via a feasibility test, preferably a column test at labscale or pilot scale (Figure 3), with real representative water from the site. Aims of these tests are (1) To evaluate the performance of the activated drain, (2) to evaluate the impact of co-pollutants, drain filling materials and the interaction between the different removal processes, and (3) to deduce degradation/removal rates and other parameters that are needed for the design of a larger scale activated drain system.

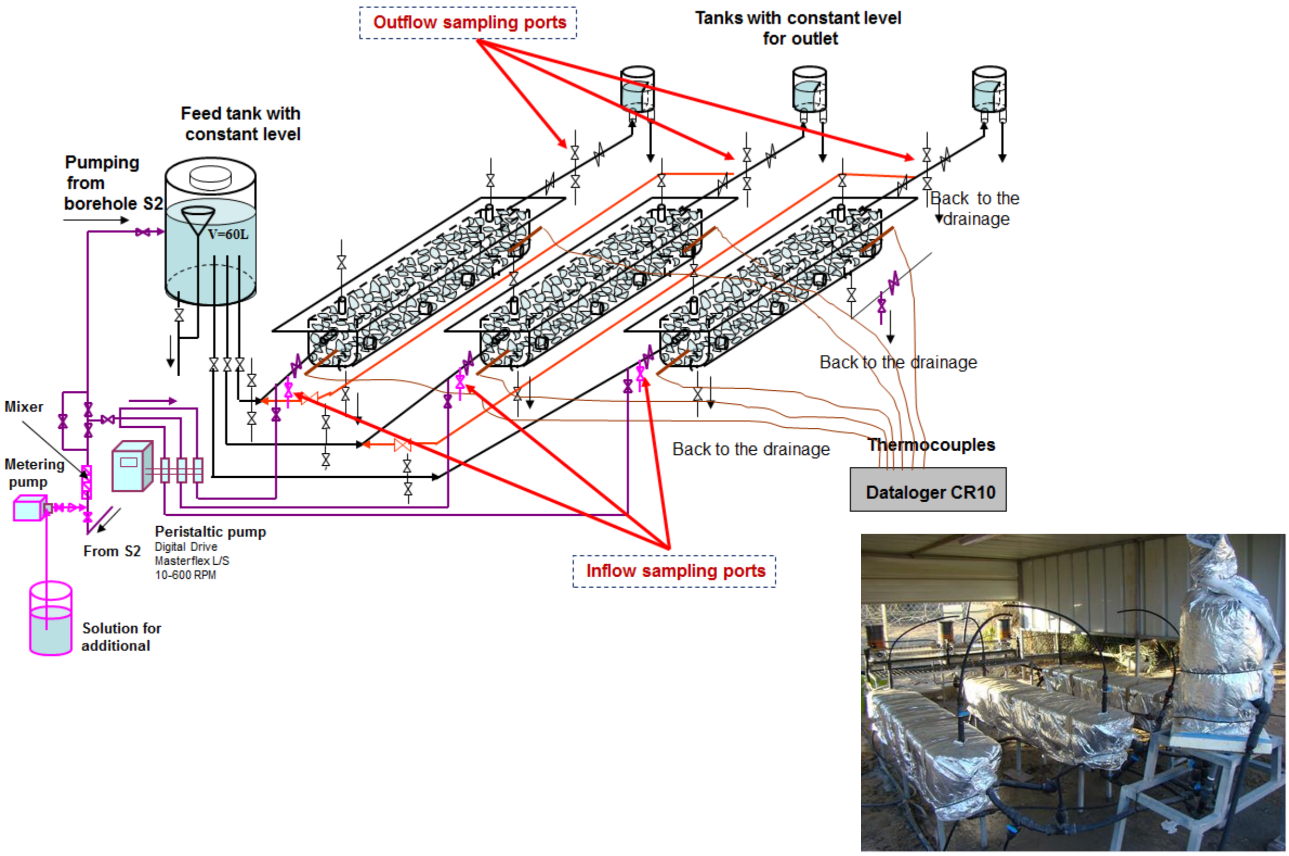

Figure 3. A schematic representation of a pilot scale treatment system constructed in the field within the AQUAREHAB project.

Step 4: Design & dimensioning full scale

Design parameters comprise (1) dimension and orientation of the drain to intercept to water (Figure 4) and (2) engineering of the pollutant removal process (selection carrier, additives, required hydraulic retention time, required length of the activated drain, …).

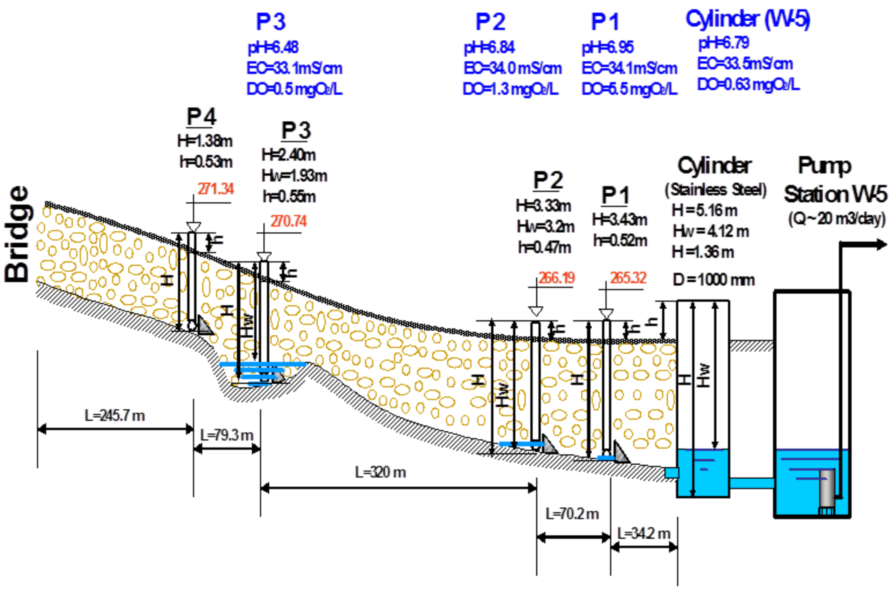

Figure 4. Example of a drain design for fractured rock. The system includes observation wells along the trench, enables monitoring of the water composition evolution as well as changes in water level. At the end of the trench, a shaft with an automated pump is installed.

Step 5: Implementation of the activated drain

This step comprises the installation of the activated drain conform to the design parameters.

Figure 5. Pictures showing the trenches dug perpendicular to the main flow direction in fractures to focus groundwater flow technology.

Step 6: Monitoring performance & corrective actions

A post installation monitoring aims at following the performance of the activated drain, where reduced pollutant concentrations along the activated drain, and at the discharge point are followed in time.

7 CONTACTS

This document was composed with input from:

Company/Institute	Contact person(s)	Contribution
Ben-Gurion University of the Negev (Israel)	Noam Weisbrod weisbrod@bgu.ac.il Zeev Roonen zeevrone@bgu.ac.il Eilon Adar M. Cohan Y. Amiaz	General concept Pesticide biodegradation Design & implementation pilot test modelling
CTM Centre Tecnologic (Spain)	Vicens Marti vicens.marti@ctm.com.es Montse Calderer montse.calderer@ctm.com.es	Screening & design carrier materials Pesticide biodegradation
Catholic University of Leuven (Belgium)	Dirk Springael dirk.springael@biw.kuleuven.be Steffi Herrmann	Screening carrier material Pesticide biodegradation
Geological Survey of Denmark and Greenland (Denmark)	Jens Aamands jeaa@geus.dk Sebastian Sorensen srs@geus.dk	Pesticide biodegradation
VITO NV (Belgium)	Leen Bastiaens leen.bastiaens@vito.be	General concept

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